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(54) Title: POLYOLEFIN PRODUCTION

(57) Abstract

A metallocene catalyst component for use in preparing polyolefins having a monomer length of up to C10, which component has the general formula:  $R''(C_pR_1R_2R_3)(C_{p'}R_1'R_2')MQ_2$  wherein  $C_p$  is a substituted or unsubstituted cyclopentadienyl ring;  $C_{p'}$  is a substituted fluorenyl ring;  $R''$  is a structural bridge imparting stereorrigidity to the component;  $R_1$  is optionally a substituent on the cyclopentadienyl ring which is distal to the bridge, which distal substituent comprises a bulky group of the formula  $XR^*_3$  in which X is chosen from Group IVA, and each  $R^*$  is the same or different and chosen from hydrogen or hydrocabyl of from 1 to 20 carbon atoms,  $R_2$  is optionally a substituent on the cyclopentadienyl ring which is proximal to the bridge and positioned *non-vicinal* to the distal substituent and is of the formula  $YR^{\#}3$  in which Y is chosen from group IVA, and each  $R^{\#}$  is the same or different and chosen from hydrogen or hydrocabyl of 1 to 7 carbon atoms,  $R_3$  is optionally a substituent on the cyclopentadienyl ring which is proximal to the bridge and is a hydrogen atom or is of the formula  $ZR^{\$}3$ , in which Z is chosen from group IVA, and each  $R^{\$}$  is the same or different and chosen from hydrogen or hydrocarbyl of 1 to 7 carbon atoms,  $R_1'$  and  $R_2'$  are each independently substituent groups on the fluorenyl ring, one of which is a group of the formula  $AR^{'''}3$ , in which A is chosen from Group IVA, and each  $R^{'''}$  is independently hydrogen or a hydrocarbyl having 1 to 20 carbon atoms and the other is hydrogen or a second group of the formula  $AR^{'''}3$ ; M is a Group IVB transition metal or vanadium; and each Q is hydrocarbyl having 1 to 20 carbon atoms or is a halogen.

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## POLYOLEFIN PRODUCTION

### Field of the Invention

The present invention relates to a metallocene catalyst component for use in preparing polyolefins, especially polypropylenes. The invention further relates to a catalyst system which incorporates the metallocene catalyst component and a process for preparing such polyolefins.

### Background to the Invention

Olefins having 3 or more carbon atoms can be polymerised to produce a polymer with an isotactic stereochemical configuration. For example, in the polymerisation of propylene to form polypropylene, the isotactic structure is typically described as having methyl groups attached to the tertiary carbon atoms of successive monomeric units on the same side of a hypothetical plane through the main chain of the polymer. This can be described using the Fischer projection formula as follows:



Another way of describing the structure is through the use of NMR spectroscopy. Bovey's NMR nomenclature for an isotactic pentad is ... mmmm with each "m" representing a "meso" diad or successive methyl groups on the same side in the plane.

In contrast to the isotactic structure, syndiotactic polymers are those in which the methyl groups attached to the tertiary carbon atoms of successive monomeric units in the chain lie on alternate sides of the plane of the polymer. Using the Fischer projection formula, the structure of a syndiotactic polymer is described as follows:

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In NMR nomenclature, a syndiotactic pentad is described as ...rrrr... in which "r" represents a "racemic" diad with successive methyl groups on alternate sides of the plane.

In contrast to isotactic and syndiotactic polymers, an atactic polymer exhibits no regular order of repeating unit. Unlike syndiotactic or isotactic polymers, an atactic polymer is not crystalline and forms essentially a waxy product.

While it is possible for a catalyst to produce all three types of polymer, it is desirable for a catalyst to produce predominantly an isotactic or syndiotactic polymer with very little atactic polymer. C<sub>2</sub>-symmetric metallocene catalysts are known in the production of the polyolefins. For example, C<sub>2</sub> symmetric bis indenyl type zirconocenes which can produce high molecular weight high melting isotactic polypropylene. The preparation of this metallocene catalyst is costly and time-consuming, however. Most importantly, the final catalyst consists of a mixture of racemic and meso isomers in an often unfavourable ratio. The meso stereoisomer has to be separated to avoid the formation of atactic polypropylene during the polymerisation reaction.

EP-A-0426644 relates to syndiotactic copolymers of olefins such as propylene obtainable using as a catalyst component isopropyl (fluorenyl)(cyclopentadienyl) zirconium dichloride. Syndiotacticity, as measured by the amount of syndiotactic pentads, rrrr was found to be 73-80%.

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EP 747406 relates to the polymerisation of an olefin monomer to form a syndiotactic/isotactic block polyolefin, particularly a block polypropylene. A component of the polymerisation catalyst was a 3-trimethylsilyl cyclopentadienyl-9-fluorenyl zirconium or hafnium dichloride having an isopropylidene or diphenylmethyliidene bridge.

EP-A-0537130 discloses the use of a C1 symmetric metallocene catalysts for the production of isotactic polypropylene. A preferred catalyst is isopropylidine (3-tert butyl-cyclopentadienyl-fluorenyl) ZrCl<sub>2</sub>. This catalyst has a bulky t-butyl group positioned on the cyclopentadienyl ring distal to the isopropylidene bridge. This catalyst has the advantage that it consists of only one stereoisomer and so no isomeric metallocene separation is required at the final stage of its synthesis. Whilst polypropylene preparation using this catalyst produces isotactic polypropylene, the polymer product has poor mechanical properties because of the presence of regiodefects and relatively low molecular weight.

Regiodefects occur in the polymer chain when, instead of producing a perfect isotactic polyolefin in which each monomeric unit is positioned head-to-tail in relation to the next, mis-insertions of the monomers occur so as to give either a head-to-head or tail-to-tail mis-match. These so called (2-1) regiodefects are partially transferred to the so called (1-3) insertion through an isomerisation process leaving units of four CH<sub>2</sub> groups in the backbone of the polypropylene chain. This has a deleterious effect on the physical and mechanical properties of the polymer and results in low molecular weight isotactic polypropylene with a low melting point. EP-A-088236 addresses this problem by providing isopropylidene (5-methyl-3t-butyl cyclopentadienyl fluorene) zirconium dichloride as part of a polymerisation

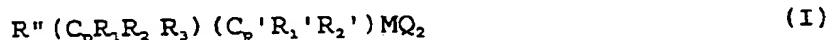
- 4 -

catalyst. However, polypropylenes obtained using this catalyst have molecular weights ( $M_w$ ) in the range 213900 to 458500 and a microtacticity characterised by the mmmmm pentad in the range 82.8% to 86.8%. The melting temperature of these polymers is in the range 139.3 to 143.8.

Summary of the Invention

The present invention aims to overcome the disadvantages of the prior art.

In a first aspect, the present invention provides a metallocene catalyst component for use in preparing polyolefins having a monomer length of up to C10, which component has the general formula:



wherein  $C_p$  is a substituted or unsubstituted cyclopentadienyl ring;  $C_{p'}$  is a substituted fluorenyl ring;  $R''$  is a structural bridge imparting stereorigidity to the component;  $R_1$  is optionally a substituent on the cyclopentadienyl ring which is distal to the bridge, which distal substituent comprises a bulky group of the formula  $XR^*$ , in which X is chosen from Group IVA, and each  $R^*$  is the same or different and chosen from hydrogen or hydrocarbyl of from 1 to 20 carbon atoms,  $R_2$  is optionally a substituent on the cyclopentadienyl ring which is proximal to the bridge and positioned non-vicinal to the distal substituent and is of the formula  $YR^{\#}$ , in which Y is chosen from group IVA, and each  $R^{\#}$  is the same or different and chosen from hydrogen or hydrocarbyl of 1 to 7 carbon atoms,  $R_3$  is optionally a substituent on the cyclopentadienyl ring which is proximal to the bridge and is a hydrogen atom or is of the formula  $ZRS$ , in which Z is

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chosen from group IVA, and each R\$ is the same or different and chosen from hydrogen or hydrocarbyl of 1 to 7 carbon atoms. R<sub>1</sub>' and R<sub>2</sub>' are each independently substituent groups on the fluorenyl ring, one of which is a group of the formula AR''', in which A is chosen from Group IVA, and each R''' is independently hydrogen or a hydrocarbyl having 1 to 20 carbon atoms and the other is hydrogen or a second group of the formula AR'''; M is a Group IVB transition metal or vanadium; and each Q is hydrocarbyl having 1 to 20 carbon atoms or is a halogen.

Polyolefins produced using the metallocene catalyst component of the present invention are surprisingly found to have very good microtacticity, especially as determined by pentad distribution levels in <sup>13</sup>C nmr. The polyolefins are also found to be substantially free of regiodefects. Accordingly, the polyolefins produced thereby have improved mechanical properties including a high weight average molecular weight typically in excess of 500,000 and melting point elevated by at least 10°C as compared with prior art values.

The applicants have unexpectedly found that if in the metallocene catalysts the fluorenyl ring is substituted in certain specific positions, preferably in position 3 and/or 6, there is a significant improvement in the tacticity of the produced polymer, and a dramatic drop in the regio-defects of said polymer.

According to the present invention, the fluorenyl ring may be substituted by radicals of general formula: AR''', where A is preferably carbon or silicon and is more preferably carbon. Where A is carbon, AR''' may be a hydrocarbyl selected from alkyl, aryl, alkenyl, alkyl aryl or aryl alkyl, such as

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methyl, ethyl, propyl, isopropyl, butyl, isobutyl, amyl, isoamyl, hexyl, heptyl, octyl, nonyl, decyl, cetyl or phenyl. Where A is silicon, AR''', may be Si(CH<sub>3</sub>)<sub>3</sub>. Preferably at least one of R'<sub>1</sub> and R'<sub>2</sub> is t-butyl. More preferably both R'<sub>1</sub> and R'<sub>2</sub> are the same.

In addition, the applicants have also found that when catalysts of the invention are used to produce polypropylene, they show melting points generally higher than 150°C and which may even reach 165°C which is a considerable improvement over the prior art.

The structural bridge R" is preferably alkylidene having 1 to 20 aliphatic or aromatic carbon atoms, a dialkyl germanium or silicon or siloxane, alkyl phosphene or amine bridging the two C<sub>p</sub> rings. R" is preferably isopropylidene in which the two C<sub>p</sub> rings are bridged at position 2 of the isopropylidene. Alternatively, R" is diphenylmethylidene.

M is preferably zirconium or titanium, most preferably zirconium. Q may be a hydrocarbyl such as alkyl, aryl, alkenyl, alkylaryl or aryl alkyl, preferably methyl, ethyl, propyl, isopropyl, butyl, isobutyl, amyl, isoamyl, hexyl, heptyl, octyl, nonyl, decyl, cetyl or phenyl. Q is preferably a halogen.

The selection of the substitution pattern on the cyclopentadienyl ring depends on the desired stereochemistry of the polyolefin product. The metallocene catalyst component of the present invention may be used to produce syndiotactic polyolefins, isotactic polyolefins or syndiotactic/isotactic block polyolefins. The polyolefins can be homopolymers or copolymers. Where a syndiotactic polyolefin is required, it is preferred that the

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cyclopentadienyl ring is unsubstituted. Where a syndiotactic/isotactic polyolefin is required, it is preferred that the cyclopentadienyl ring is substituted at a position distal to the bridge. R<sub>1</sub> is therefore not hydrogen but is instead a substituent on the cyclopentadienyl ring. It is preferred that R<sub>1</sub> is a bulky distal substituent group.

In the bulky distal substituent group R<sub>1</sub>, X is preferably C or Si. R\* may be a hydrocarbyl such as alkyl, aryl, alkenyl, alkylaryl or aryl alkyl, preferably methyl, ethyl, propyl, isopropyl, butyl, isobutyl, amyl, isoamyl, hexyl, heptyl, octyl, nonyl, decyl, cetyl or phenyl. R<sub>1</sub> may comprise a hydrocarbyl which is attached to a single carbon atom in the cyclopentadienyl ring or may be bonded to two carbon atoms in that ring. Preferably, R<sub>1</sub> is C(CH<sub>3</sub>)<sub>3</sub>, C(CH<sub>3</sub>)<sub>2</sub>Ph, CPh<sub>3</sub> or Si(CH<sub>3</sub>)<sub>3</sub>, most preferably C(CH<sub>3</sub>)<sub>3</sub>.

Where an isotactic polyolefin is required, it is preferred that both R<sub>1</sub> and R<sub>2</sub> are not hydrogen. R<sub>2</sub> is a substituent on the cyclopentadienyl ring which is proximal to the bridge and preferably comprises a CH<sub>3</sub> group.

The cyclopentadienyl ring may also be substituted by R<sub>1</sub> in isotactic polyolefin production. R<sub>1</sub> is preferably CH<sub>3</sub>.

In a further aspect, the present invention provides a metallocene catalyst component for use in preparing polyolefins, which comprises (i) a catalyst component as defined above; and (ii) a regioisomer thereof in which R<sub>2</sub> is proximal to the bridge and positioned vicinal to the distal substituent.

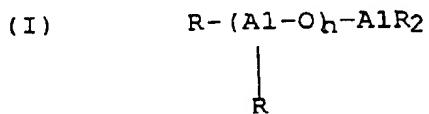
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Such regioisomers are frequently relatively easy to prepare because they are formed as a "by-product" during the synthetic route by which the catalyst component (i) may be made.

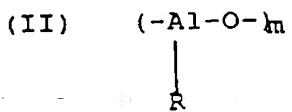
Surprisingly, it has been found that catalyst components including both regioisomers can be used in the preparation of polyolefins which have a multimodal, especially a bimodal, molecular weight distribution.

In a further aspect, the present invention provides a catalyst system for use in preparing polyolefins, which comprises (a) a catalyst component as defined above; and (b) an aluminium- or boron-containing cocatalyst capable of activating the catalyst component. Suitable aluminium-containing cocatalysts comprise an alumoxane, an alkyl aluminium and/or a Lewis acid.

The alumoxanes usable in the process of the present invention are well known and preferably comprise oligomeric linear and/or cyclic alkyl alumoxanes represented by the formula:



for oligomeric, linear alumoxanes and



for oligomeric, cyclic alumoxane,

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wherein n is 1-40, preferably 10-20, m is 3-40, preferably 3-20 and R is a C<sub>1</sub>-C<sub>8</sub> alkyl group and preferably methyl. Generally, in the preparation of alumoxanes from, for example, aluminium trimethyl and water, a mixture of linear and cyclic compounds is obtained.

Suitable boron-containing cocatalysts may comprise a triphenylcarbenium boronate such as tetrakis-pentafluorophenyl-borato-triphenylcarbenium as described in EP-A-0427696, or those of the general formula [L'-H] + [B Ar, Ar, X, X<sub>1</sub>]- as described in EP-A-0277004 (page 6, line 30 to page 7, line 7).

The catalyst system may be employed in a solution polymerisation process, which is homogeneous, or a slurry process, which is heterogeneous. In a solution process, typical solvents include hydrocarbons with 4 to 7 carbon atoms such as heptane, toluene or cyclohexane. In a slurry process it is necessary to immobilise the catalyst system on an inert support, particularly a porous solid support such as talc, inorganic oxides and resinous support materials such as polyolefin. Preferably, the support material is an inorganic oxide in its finally divided form.

Suitable inorganic oxide materials which are desirably employed in accordance with this invention include Group 2a, 3a, 4a or 4b metal oxides such as silica, alumina and mixtures thereof. Other inorganic oxides that may be employed either alone or in combination with the silica, or alumina are magnesia, titania, zirconia, and the like. Other suitable support materials, however, can be employed, for example, finely divided functionalized polyolefins such as finely divided polyethylene.

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Preferably, the support is a silica having a surface area comprised between 200 and 700 m<sup>2</sup>/g and a pore volume comprised between 0.5 and 3 ml/g.

The amount of alumoxane and metallocenes usefully employed in the preparation of the solid support catalyst can vary over a wide range. Preferably the aluminium to transition metal mole ratio is in the range between 1:1 and 100:1, preferably in the range 5:1 and 50:1.

The order of addition of the metallocenes and alumoxane to the support material can vary. In accordance with a preferred embodiment of the present invention alumoxane dissolved in a suitable inert hydrocarbon solvent is added to the support material slurried in the same or other suitable hydrocarbon liquid and thereafter a mixture of the metallocene catalyst component is added to the slurry.

Preferred solvents include mineral oils and the various hydrocarbons which are liquid at reaction temperature and which do not react with the individual ingredients. Illustrative examples of the useful solvents include the alkanes such as pentane, iso-pentane, hexane, heptane, octane and nonane; cycloalkanes such as cyclopentane and cyclohexane, and aromatics such as benzene, toluene, ethylbenzene and diethylbenzene.

Preferably the support material is slurried in toluene and the metallocene and alumoxane are dissolved in toluene prior to addition to the support material.

In a further aspect, the present invention provides use of a catalyst component as defined above and a cocatalyst which activates the catalyst component, for the preparation of

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polyolefins, preferably polypropylenes. Although the present invention is dedicated to the use of metallocene catalysts, the fluorenyl ring of which has been substituted in positions 3 and/or 6, it has been noted that by using a metallocene catalyst component comprising (i) the catalytic component and (ii) a regioisomer thereof, in which R<sub>2</sub> is proximal to the bridge and positioned vicinal to the distal substituent, for the preparation of polyolefins, especially polypropylenes, having a multimodal molecular weight distribution, preferably a bimodal molecular weight distribution.

In a further aspect, the present invention provides a process for preparing polyolefins, especially polypropylenes, which comprises contacting a catalyst system as defined above with at least one olefin, preferably propylene, in a reaction zone under polymerisation conditions.

The catalyst component may be prepared by any suitable method known in the art. Generally, the preparation of the catalyst component comprises forming and isolating bridged dicyclopentadiene, which is then reacted with a halogenated metal to form the bridged metallocene catalyst.

In one embodiment, the process for preparing the bridged metallocene catalyst components comprises contacting the cyclopentadiene with a substituted fluorene under reaction conditions sufficient to produce a bridged dicyclopentadiene. The process further comprises contacting the bridged substituted dicyclopentadiene with a metal compound of the formula MQ<sub>k</sub> as defined above under reaction conditions sufficient to complex the bridged dicyclopentadiene to produce a bridged metallocene wherein M and Q are each defined as above and 0 ≤ k ≤ 4. The process step of

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contacting the bridged substituted dicyclopentadiene with a metal compound can be performed in a chlorinated solvent.

In a further embodiment, the process comprises contacting the cyclopentadiene with an alkyl silyl chloride of the formula R<sup>n</sup>Si Hal, wherein R<sup>n</sup> is a hydrocarbyl having 1 to 20 carbon atoms and Hal is a halogen. A second equivalent of a substituted fluorene is added to produce a silicon bridged cyclopentadienyl-substituent fluorenyl ligand. The subsequent steps are similar to those above for producing a bridged substituted cyclopentadienyl-fluorenyl ligand coordinated to metals such as Zr, Hf and Ti.

In a further embodiment, the process comprises contacting the substituted cyclopentadiene with a fulvene producing agent such as acetone to produce a substituted fulvene. Subsequently, in a second step, the fulvene is reacted with a fluorene substituted in position 3 and/or 6, and preferably both 3 and 6, to produce a carbon bridged substituted cyclopentadienyl-fluorenyl ligand that will produce the desired metallocene catalysts after reacting with MCl<sub>4</sub>, in which M is Zr, Hf or Ti.

In a further aspect, the present invention provides an isotactic polyolefin having a monomer length of up to C10 and a pentad distribution comprising greater than 80% and preferably at least 87% mmmmm as measured by <sup>13</sup>C nmr. The pentad distribution preferably comprises at least 90%, more preferably at least 95% mmmmm as measured by <sup>13</sup>C nmr. Preferably, the amount 2-1 and 1-3 monomer insertions in the polyolefin is less than 0.5%, more preferably, less than 0.2 and most preferably undetectable.

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In a further aspect, the present invention provides a syndiotactic polyolefin having a monomer length of up to C10 and a pentad distribution comprising at least 85% rrrr as measured by  $^{13}\text{C}$  nmr. Preferably, the pentad distribution comprises at least 90%, more preferably at least 94% rrrr as measured by  $^{13}\text{C}$  nmr.

The invention will now be described in further detail, by way of example only, with reference to the attached drawings in which:

FIGURES 1 to 12 show illustrations of the structures of preferred catalyst components of the present invention; and

FIGURE 13 shows the results of differential scanning calorimetry analysis on isotactic polypropylene produced at 40°C using the catalyst shown in Figure 1.

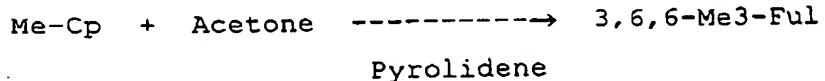
Example 1

Preparation of isopropylidene [(3-tertbutyl-5-methylcyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)] zirconium dichloride

A. Preparation of 3,6,6-trimethylfulvene

Reaction

Methanol



Procedure

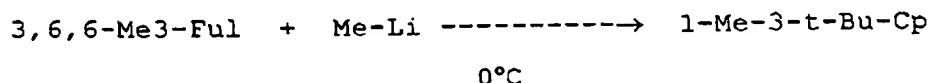
- 14 -

In a round bottom flask equipped with magnetic stirring bar and N<sub>2</sub> inlet is placed 350 ml of methanol (at -78°C) containing freshly prepared methylcyclopentadiene under N<sub>2</sub>. To this solution is added a solution of 28.6 g (0.493 mol) of acetone in 50 ml of methanol dropwise. Subsequently 52.5 g (0.738 mol) of pyrrolidene is added. The reaction mixture is stirred at ambient temperature for 24 hours. After neutralisation with acetic acid and separation of the organic phase the solvent is evaporated and the remaining yellow oil is subjected to distillation. A mixture of 3,6,6-Me<sub>3</sub>-Ful and 2,6,6-Me<sub>3</sub>-Ful is obtained in 65% yield.

B. Preparation of 1-methyl-3-tert-butylcyclopentadiene

Reaction

Ether



Procedure

50 g (0.417 mol) of 3,6,6-Me<sub>3</sub>-t-Bu-Ful is placed in a 1 litre flask and dissolved in 500 ml of diethyl ether and cooled down to 0°C. To the solution is added dropwise 260.4 ml (0.417 mol) of methyllithium in ether (1.6 mol). The reaction is completed after a few hours. After adding 75 ml of saturated solution of NH<sub>4</sub>Cl in water, the organic phase is separated and dried with MgSO<sub>4</sub>. The evaporation of the solvent leads to the isolation of a yellow oil. After distillation, 33.65 g (59.28%) of 1-Me-3-t-Bu-Cp is obtained.

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**C. Preparation of 1,6,6-trimethyl-3-tert-butylfulvene**

Reaction

Methanol



Pyrrolidene

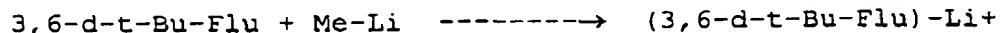
Procedure

In a 1 l flask is placed 30 g (0.220 mol) of 1-Me-3-t-Bu-Cp and dissolved in 60 ml of methanol. The mixture is cooled down to -78°C. 5.11 g (0.088 mol) of acetone in 20 ml of methanol is added slowly. In the next step, 9.4 g (0.132 mol) of pyrrolidene in 20 ml of methanol is added. After a week, the reaction is terminated by addition of 20 ml of acetic acid. After separation of the organic phase, drying, evaporation of solvents and distillation, 16.95 g of an orange oil is obtained (yield, 43.66%).

**D. Preparation of 2,2-[(3-tertbutyl-5-methylcyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]-propane**

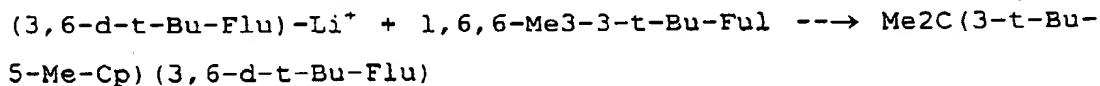
Reaction

THF



0°C

THF



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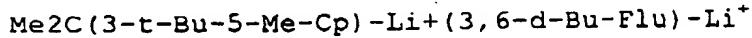
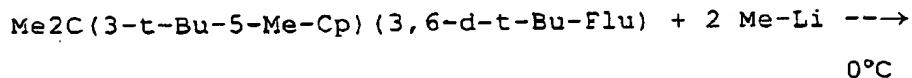
Procedure

1.5 g (5.387 mmol) of 3,6-d-t-Bu-Flu in 100 ml of dry tetrahydrofuran, is placed into a 250 ml flask, under N<sub>2</sub> and the solution is pre-cooled to 0°C. The 3,6-d-t-Bu-Flu may be synthesised according to Shoji Kajigaeshi et al. Bull. Chem. Soc. Jpn. 59, 97-103(1986) or M Bruch et al. Liebigs Ann. Chem. 1976, 74-88. Then, a solution of 3.4 ml (5.387 mmol) of methyllithium is added drop wise to the solution. The solution is red and is further continued at room temperature during 4 hours. After that, a solution of 0.9497 g (5.382 mmol) of 1,6,6-Me<sub>3</sub>-3-t-Bu-Ful in 10 ml of dry tetrahydrofuran is added dropwise to this solution. The reaction is further continued during 24 hours. After adding 40 ml of saturated solution of NH<sub>4</sub>Cl in water, the yellow organic phase is separated and dried with MgSO<sub>4</sub> anhydrous. The evaporation of the solvent leads to the isolation of 2.36 g (yield, 96.32%) of orange solid product.

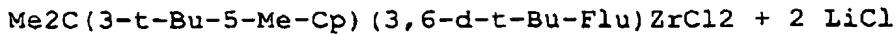
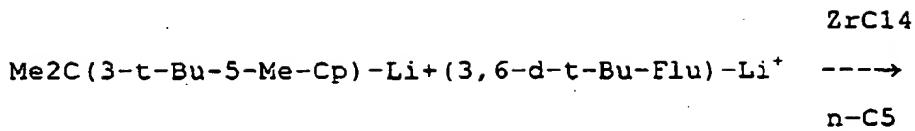
E. Preparation of isopropylidene [(3-tertbutyl-5-methyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)] zirconium dichloride (1)

Reaction

THF



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Procedure

2 g (4.398 mmol) of ligand is dissolved in 100 ml of dry tetrahydrofuran under N<sub>2</sub>, and the solution is pre-cooled to 0°C. A solution of 5.5 ml (8.796 mmol) of methyllithium (1.6 mol/diethyl ether) is added dropwise to this solution. After 3 hours, the solvent is removed in vacuum, the red powder is washed with 2 x 100 ml of pentane. The red dianion ligand and 100 ml of pentane are placed into a 250 ml flask, under N<sub>2</sub>. 1.02 g (4.398 mmol) of zirconium tetrachloride is added to this suspension. The reaction mixture is red-brown and stirred overnight in a glove box. After filtration, the orange solution is removed in vacuo at 40°C and yielded 2.3 g (85.18%) of orange powder. Apparently, this metallocene is soluble in pentane. According the <sup>1</sup>H NMR of the product it seems that a second isomer with a chemical structure of isopropylidene (2(or 4)-methyl-3-tertbutylcyclopentadienyl-3,6-diterbetylfluorenyl)ZrCl<sub>2</sub> (2) is formed as the second product which is less stereoregular.

Example 2

Preparation of isopropylidene [(cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)] zirconium dichloride

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The synthetic procedure according to Example 1 is followed except that the ligand in step D is replaced by the 2,2-[(cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]-propane.

A. Preparation of 2,2-[(cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]-propane

Procedure

The preparation of this ligand is the same as described in Example 1, step D, except that the 1,6,6-trimethyl-3-tert-butylfulvene is replaced by 0.5720 g (5.387 mmol) of 6,6-dimethylfulvene.

Example 3

Preparation of isopropylidene [(3-methyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)] zirconium dichloride

The synthetic procedure according to Example 1 is followed except that the ligand in step D is replaced by the 2,2-[(3-methyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]-propane.

A. Preparation of 2,2-[(3-methyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]-propane

Procedure

- 19 -

The preparation of this ligand is the same as that of step D, but the 1,6,6-trimethyl-3-tert-butylfulvene is replaced by 0.6475 g (5.387 mmol) of 3,6,6-trimethylfulvene (the synthetic procedure is described in Example 1, step A).

Example 4

Preparation of isopropylidene [(3-tertbutyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)] zirconium dichloride

The synthetic procedure according to Example 1 is followed except that the ligand in step D is replaced by the 2,2-[(3-tertbutyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]-propane prepared as below.

A. Preparation of 2,2-[(3-tertbutyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]-propane

Procedure

The preparation of this ligand is the same that the step D, but the 1,6,6-trimethyl-3-tert-butylfulvene is replaced by 0.8742 g (5.387 mmol) of 6,6-dimethyl-3-tert-butylfulvene.

B. Preparation of 6,6-dimethyl-3-tert-butylfulvene

Procedure

The synthetic procedure according to Example 1, step A, is followed, but the methylcyclopentadiene is replaced by the tert-butylcyclopentadiene.

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C. Preparation of tert-butylcyclopentadiene

Procedure

The synthetic procedure according to Example 1, step B, is followed, but the 3,6,6-trimethylfulvene is replaced by 6,6-dimethylfulvene.

Example 5a

Preparation of isopropylidene[(3-trimethylsilyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]zirconium dichloride

The synthetic procedure according to Example 1 is followed except that the ligand in step D is replaced by the diphenyl[(3-trimethylsilyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]methylenne.

A. Preparation of 2,2-[(3-trimethylsilyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]propane

Procedure

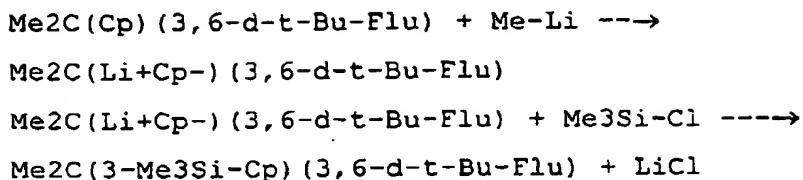
The preparation of this ligand is the same as described in Example 1, step D, except that the 1,6,6-trimethyl-3-tert-butylfulvene is replaced by 1.2407 g (5.387 mmol) of 6,6-dimethylfulvene.

B. Preparation of 2,2-[(3-trimethylsilyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]propane

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Reaction

THF



Procedure

First, in a 1 l flask, 10 g (0.026 mol) of 2,2-(cyclopentadienyl)(3,6-di-tertbutyl-fluroenyl)propane is dissolved in 300 ml of tetrahydrofuran under N<sub>2</sub>. Then 16.25 ml (0.026 mol) of methyllithium is added dropwise to this solution at room temperature (the flask is pre-cooled with a water bath). After a stirring period of one hour, 3.3 ml (0.026 mol) of chlorotrimethylsilane, is added to this solution. The reaction mixture is stirred for an additional 3 hours. Then the solvent is removed in vacuo. One litre of pentane is added to the solid orange residue. The reaction mixture is heated at 40°C for 10 minutes. The orange solution is filtered (to remove LiCl, 1.40 g of residue), concentrated to 100 ml, and cooled down to crystallise the product 2,2-(3-trimethylsilyl-cyclopentadienyl)fluorenylpropane. The raw product has a beige colour. The crystallised product has a white colour, 65-70% yield. The product was stored under N<sub>2</sub>.

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Example 5b

Preparation of diphenylmethyldene[(3-trimethylsilyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]zirconium dichloride

The synthetic procedure according to Example 1 is followed except that the ligand in step D is replaced by the diphenyl[(3-trimethylsilyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]methylenne.

A. Preparation of 1,1,1,1-diphenyl[(3-trimethylsilyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]methane

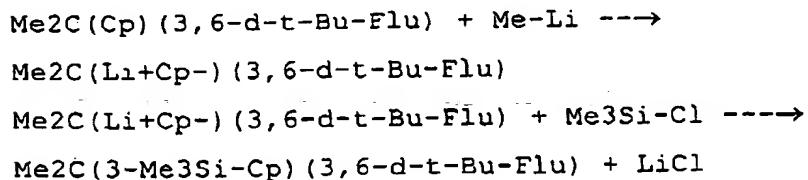
Procedure

The preparation of this ligand is the same as described in Example 1, step D, except that the 1,6,6-trimethyl-3-tertbutylfulvene is replaced by 1.2407 g (5.387 mmol) of 6,6-dimethylfulvene.

B. Preparation of diphenyl[(3-trimethylsilyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]methane

Reaction

THF



- 23 -

Procedure

First, in a 1 l flask, 10 g (0.026 mol) of 2,2-(cyclopentadienyl)(3,6-di-tertbutyl-fluorenyl)propane is dissolved in 300 ml of tetrahydrofuran under N<sub>2</sub>. Then 16.25 ml (0.026 mol) of methyllithium is added dropwise to this solution at room temperature (the flask is pre-cooled with a water bath). After a stirring period of one hour, 3.3 ml (0.026 mol) of chlorotrimethylsilane, is added to this solution. The reaction mixture is stirred for an additional 3 hours. Then the solvent is removed in vacuo. One litre of pentane is added to the solid orange residue. The reaction mixture is heated at 40°C for 10 minutes. The orange solution is filtered (to remove LiCl, 1.40 g of residue), concentrated to 100 ml, and cooled down to crystallise the product 2,2-(3-trimethylsilyl-cyclopentadienyl)-(3,6-di-tertbutyl fluorenyl)propane. The raw product has a beige colour. The crystallised product has a white colour, 65-70% yield. The product was stored under N<sub>2</sub>.

Example 6

Preparation of isopropylidene[(3,5-dimethyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)] zirconium dichloride

The synthetic procedure according to Example 1 is followed except that the ligand in step D is replaced by the 2,2-[(3,5-dimethyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]-propane.

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A. Preparation of 2,2-[(3,5-dimethyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]-propane

Procedure

The preparation of this ligand is the same as in Example 1 step D, but the 1,6,6-trimethyl-3-tert-butylfulvene is replaced by 0.8742 g (5.387 mmol) of 1,3,6,6-tetramethylfulvene.

B. Preparation of 1,3,6,6-tetramethylfulvene

The synthetic procedure according to Example 1 step A, is followed but the methylcyclopentadiene is replaced by 1,3-dimethylcyclopentadiene.

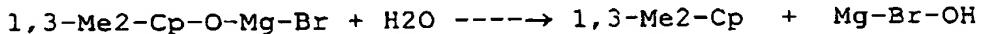
C. Preparation of 1,3-dimethylcyclopentadiene

Reaction

Ether



0°C



Procedure

195 ml (0.585 mole) of methyl magnesium bromide (solution 3.0 mole/diethyl ether) in 200 ml of dry diethyl ether, is placed into a 2 l flask, under N<sub>2</sub> and the solution is pre-cooled to

- 25 -

0°C. Then a solution of 47.15 g (0.4905 mole) of 3-methyl-2-cyclopentenone in 100 ml of diethyl ether is added dropwise to the solution for 3 hours at 0°C and for an hour at 10°C. This product is transferred into a 5 l flask pre-cooled to 0°C and containing 1 l of water. The solution is yellow. The yellow organic phase is separated and the solvent is removed in vacuo (500 mbars) at room temperature. The evaporation of the solvent leads to the isolation of a clear orange solution. After distillation 31.83 g (yield, 65.95%) of 1,3-dimethylcyclopentadiene is obtained. The product is a colourless unstable liquid and used directly for the preparation of the 1,3,6,6-trimethylfulvene.

Example 7

Preparation of diphenylmethyldene [(cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)] zirconium dichloride

The synthetic procedure according to Example 1 is followed except that the ligand in step D is replaced by the 2,2diphenyl[(cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]methylen.

A. Preparation of 1,1,1,1-diphenyl[(cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]methane

Procedure

The preparation of this ligand is the same as described in Example 1, step D, except that the 1,6,6-trimethyl-3-tert-

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butylfulvene is replaced by 1.2407 g (5.387 mmol) of 6,6-diphenylfulvene.

Example 8

Preparation of diphenylmethyldene[(3-methyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)] zirconium dichloride

The synthetic procedure according to Example 1 is followed except that the ligand in step D is replaced by the 2,2-diphenyl[(3-methyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]propane.

A. Preparation of 1,1,1,1-diphenyl[(3-methyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]methane

Procedure

The preparation of this ligand is the same as described in Example 1, step D, except that the 1,6,6-trimethyl-3-tert-butylfulvene is replaced by 1.2407 g (5.387 mmol) of 3-methyl-6,6-diphenylfulvene.

B. Preparation of 3-methyl-6,6-diphenylfulvene

Procedure

The preparation of this fulvene is the same as described in Example 1, step A, except that the acetone is replaced by 1.3162 g (5.387 mmol) of 6,6-diphenylfulvene.

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Example 9

Preparation of diphenylmethyldene[(3-tertbutyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)] zirconium dichloride

The synthetic procedure according to Example 1 is followed except that the ligand in step D is replaced by the diphenyl[(3-tertbutyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]methylen.

A. Preparation of 1,1,1,1-diphenyl[(3-tertbutyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]methane

Procedure

The preparation of this ligand is the same as described in Example 4, step A, except that the 6,6-dimethyl-3-tertbutylfulvene is replaced by the 3-tertbutyl-6,6-diphenylfulvene.

B. Preparation of 3-tertbutyl-6,6-diphenylfulvene

Procedure

The preparation of this fulvene is the same as described in Example 1, step A, except that the acetone is replaced by the benzophenone and the methylcyclopentadiene is replaced by the tert-butylcyclopentadiene (the synthetic procedure is described in Example 4, step C).

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Example 10

Preparation of diphenylmethyldene[(3-trimethylsilyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)] zirconium dichloride

The synthetic procedure according to Example 1 is followed except that the ligand in step D is replaced by the 2,2-diphenyl[(3-trimethylsilyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]propane

A. Preparation of 1,1,1,1-diphenyl[(3-trimethylsilyl-cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]methane

Procedure

The preparation of this ligand is the same as described in Example 5, step B, except that the 2,2-[(cyclopentadiene)(fluorenyl)]propane is replaced by the 2,2-diphenyl[(cyclopentadienyl)(fluorenyl)]propane.

B. Preparation of 2,2-diphenyl[(cyclopentadienyl)-(3,6-di-tertbutyl-fluorenyl)]propane

Procedure

The preparation of this ligand is the same as described in Example 1, step D, except that the 1,6,6-trimethyl-3-tertbutylfulvene is replaced by the 6,6-diphenylfulvene.

Example 11

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#### Polymerisation procedures

Each polymerisation was performed in a 4 litre bench reactor with pure propylene. Polymerisation was initiated by introducing metallocene (0.5 to 5 mg) precontacted with 1 ml of MAO (methylaluminoxane) (30% solution in toluene obtained from WITCO) three minutes prior to its introduction into the reactor.

Table 1a shows figures for production of syndiotactic polypropylene using as a catalyst component described in Example 2. Table 1b shows corresponding figures for the metallocene described in Example 7.

Table 1a

Syndiotactic polypropylene made using isopropylidene bridge catalyst

Polymerisation temp	Mw (kD)	Mp°C	Microtacticity (rrrr)
30°C	250	152-154	92-94%
40°C	200	150	90-92%
60°C	170	145	88-90%
80°C	140	142	86-88%

Table 1b

Syndiotactic polypropylene made using diphenylmethyldene bridge catalyst.

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Polymerisation temp	Mw (kD)	Mp°C	Microtacticity (rrrr)
20°C	1000	152-154	92-94%
40°C	800	150	90-92%
60°C	680	145	88-90%
80°C	350	142	86-88%

Table 2 shows the microtacticity of the polymer obtained using the catalyst according to Example 1 under polymerisation conditions as defined by the corresponding entries in Table 1. The results were obtained using  $^{13}\text{C}$  NMR spectroscopy. It will be apparent that the polypropylene contained more than 95% of pentads in the purely isotactic form (mmmm). The molecular weight (Mw) of the polypropylene was 530,000 and the melting point was 153°C. Melting point was determined by DSC analysis as shown in Figure 13. A sample was held at 25°C for 1 min, heated from 25°C to 220°C at 20°C/min and held for 5 mins at 220°C. The sample was then cooled from 220°C to 25°C at 20°C/min, held at 25°C for 3 mins and heated from 25°C to 220°C at 20°C/min.

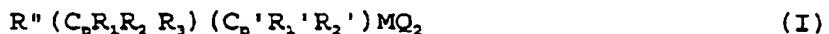
Table 2  
Pentad stereo-sequence distributions %

mmmm	95.7
mmmr	1.70
rmmr	0.00
mmrr	1.70
mrmr	0.00
+ rmrz	
mrmr	0.00
rrrr	0.00
rrrr	0.00
mrrm	0.80

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**CLAIMS:**

1. A metallocene catalyst component for use in preparing polyolefins having a monomer length of up to C<sub>10</sub>, which component has the general formula:



wherein C<sub>p</sub> is a substituted or unsubstituted cyclopentadienyl ring; C<sub>p'</sub> is a substituted fluorenyl ring; R'' is a structural bridge imparting stereorrigidity to the component; R<sub>1</sub> is optionally a substituent on the cyclopentadienyl ring which is distal to the bridge, which distal substituent comprises a bulky group of the formula X R\*, in which X is chosen from Group IVA, and each R\* is the same or different and chosen from hydrogen or hydrocarbyl of from 1 to 20 carbon atoms, R<sub>2</sub> is optionally a substituent on the cyclopentadienyl ring which is proximal to the bridge and positioned non-vicinal to the distal substituent and is of the formula Y R#, in which Y is chosen from group IVA, and each R# is the same or different and chosen from hydrogen or hydrocarbyl of 1 to 7 carbon atoms, R<sub>3</sub> is optionally a substituent on the cyclopentadienyl ring which is proximal to the bridge and is a hydrogen atom or is of the formula Z R\$, in which Z is chosen from group IVA, and each R\$ is the same or different and chosen from hydrogen or hydrocarbyl of 1 to 7 carbon atoms, R<sub>1</sub>' and R<sub>2</sub>' are each independently substituent groups on the fluorenyl ring, one of which is a group of the formula A R''', in which A is chosen from Group IVA, and each R''' is independently hydrogen or a hydrocarbyl having 1 to 20 carbon atoms and the other is hydrogen or a second group of the formula A R'''; M is a Group IVB transition metal or

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vanadium; and each Q is hydrocarbyl having 1 to 20 carbon atoms or is a halogen.

2. A catalyst component according to claim 1, wherein R<sub>1</sub>' and R<sub>2</sub>' are at positions 3 and 6 on the fluorenyl ring.

3. A catalyst component according to claim 1 or claim 2, wherein A is carbon or silicon.

4. A catalyst component according to claim 3, wherein AR''', is hydrocarbyl having from 1 to 20 carbon atoms.

5. A catalyst component according to claim 4, wherein AR''', is C(CH<sub>3</sub>)<sub>3</sub>.

6. A catalyst component according to claim 2, wherein AR''', is Si(CH<sub>3</sub>)<sub>3</sub>.

7. A catalyst component according to any one of the preceding claims, wherein R<sub>1</sub>' and R<sub>2</sub>' are the same.

8. A catalyst component according to any one of the preceding claims, wherein R" is alkylidene having 1 to 20 carbon atoms, a dialkyl germanium or silicon or siloxane, alkyl phosphine or amine.

9. A catalyst component according to claim 8, wherein R" is isopropylidene, dimethylsilanediyl or diphenylmethyliidene.

10. A catalyst component according to any one of the preceding claims, wherein M is zirconium or titanium.

11. A catalyst component according to any one of the preceding claims, wherein Q is halogen.

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12. A catalyst component according to any one of the preceding claims, wherein R<sub>1</sub> is C(CH<sub>3</sub>)<sub>3</sub>, C(CH<sub>3</sub>)<sub>2</sub>Ph, CPh, or Si(CH<sub>3</sub>)<sub>3</sub>.

13. A catalyst component according to claim 12, wherein R<sub>1</sub> is C(CH<sub>3</sub>)<sub>3</sub>.

14. A catalyst component according to any one of the preceding claims, wherein Y is carbon.

15. A catalyst component according to any one of the preceding claims, wherein Z is carbon.

16. A catalyst component according to any preceding claim, wherein R<sub>2</sub> is CH<sub>3</sub>.

17. A catalyst component according to any one of the preceding claims, wherein R<sub>2</sub> is CH<sub>3</sub>.

18. A metallocene catalyst component for use in preparing isotactic polyolefins, which component comprises isopropylidene-3-t-butyl-5-methyl-cyclopentadienyl 3,6 di t-butyl fluorenyl ZrCl<sub>2</sub>.

19. A metallocene catalyst component for use in preparing polyolefins having a monomer length of up to C10, which comprises (i) a catalyst component according to any one of the preceding claims; and (ii) a regioisomer thereof in which R<sub>2</sub> is proximal to the bridge and positioned vicinal to the distal substituent.

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20. A metallocene catalyst component for use in preparing polyolefins, which comprises isopropylidene-(3-t-butyl-5-methyl cyclopentadienyl-3,6 di t-butyl fluorenyl) ZrCl<sub>2</sub> and isopropylidene-(3-t-butyl-2-methyl cyclopentadienyl-3,6 di t-butyl fluorenyl) ZrCl<sub>2</sub>.

21. A catalyst system for use in preparing polyolefins, which comprises (a) a catalyst component according to any one of the preceding claims; and (b) an aluminium- or boron-containing co-catalyst capable of activating the catalyst component.

22. A catalyst system according to claim 17, which further comprises an inert support.

23. Use of a catalyst component according to any one of claims 1 to 11, and a cocatalyst which activates the catalyst component, for the preparation of a syndiotactic polyolefin having a monomer length of up to C10.

24. Use according to claim 23, wherein Cp is unsubstituted.

25. Use of a catalyst component according to any one of claims 1 to 13, and a cocatalyst which activates the catalyst component, for the preparation of a syndiotactic/isotactic block polyolefin having a monomer length of up to C10, wherein R<sub>1</sub> is a substituent on the cyclopentadienyl ring.

26. Use of a catalyst component according to any one of claims 1 to 17, and a cocatalyst which activates the catalyst component, for the preparation of an isotactic polyolefin having a monomer length of up to C10, wherein R<sub>1</sub> and R<sub>2</sub> are both substituents on the cyclopentadienyl ring.

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27. Use of a catalyst component according to claim 19 or claim 20, and a cocatalyst which activates the catalyst component, for the preparation of isotactic polyolefins having a monomer length of up to C10 and having a multimodal molecular weight distribution.

28. A process for preparing polyolefins having a monomer length of up to C10, which comprises contacting a catalyst system according to claim 21 or claim 22 with at least one olefin in a reaction zone under polymerisation conditions.

29. A process according to claim 28, wherein the olefin is propylene.

30. A process according to claim 28, wherein two or more olefins are present in the reaction zone to produce a polyolefin copolymer.

31. An isotactic polyolefin having a monomer length of up to C10 and a pentad distribution comprising at least 87% mmmm as measured by  $^{13}\text{C}$  nmr.

32. A polyolefin according to claim 31, wherein the pentad distribution comprises at least 95% mmmm as measured by  $^{13}\text{C}$  nmr.

33. A polyolefin according to claim 31 or claim 32, wherein the amount of 2-1 and 1-3 monomer insertions in the polyolefin is undetectable.

34. A syndiotactic polyolefin having a monomer length of up to C10 and a pentad distribution comprising greater than 80% rrrr as measured by  $^{13}\text{C}$  nmr.

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35. A syndiotactic polyolefin according to claim 34, wherein the pentad distribution comprises at least 85% rrrr as measured by  $^{13}\text{C}$  nmr.

36. A polyolefin according to any one of claims 31 to 35, which comprises a polypropylene.

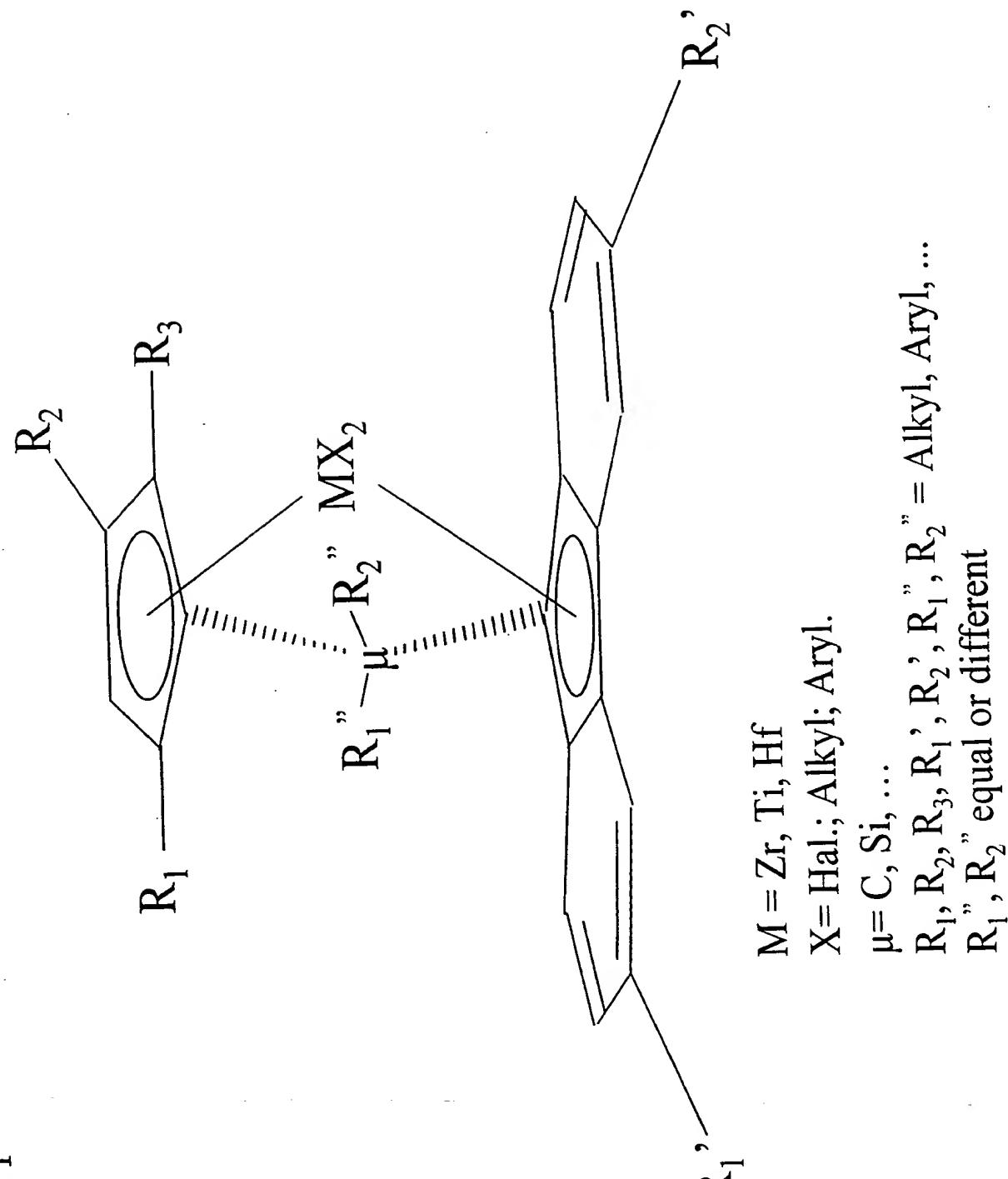


FIGURE 1

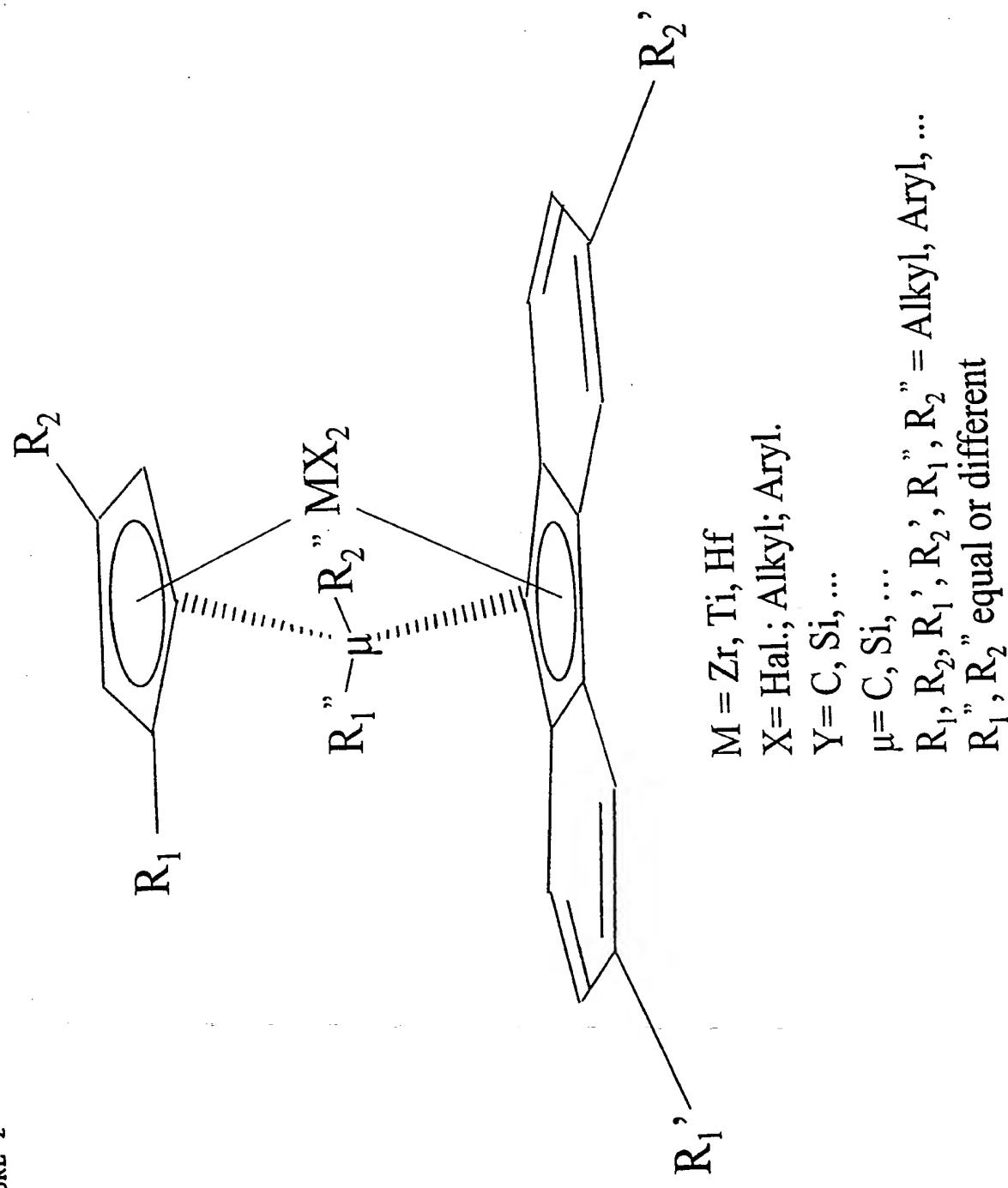


FIGURE 2

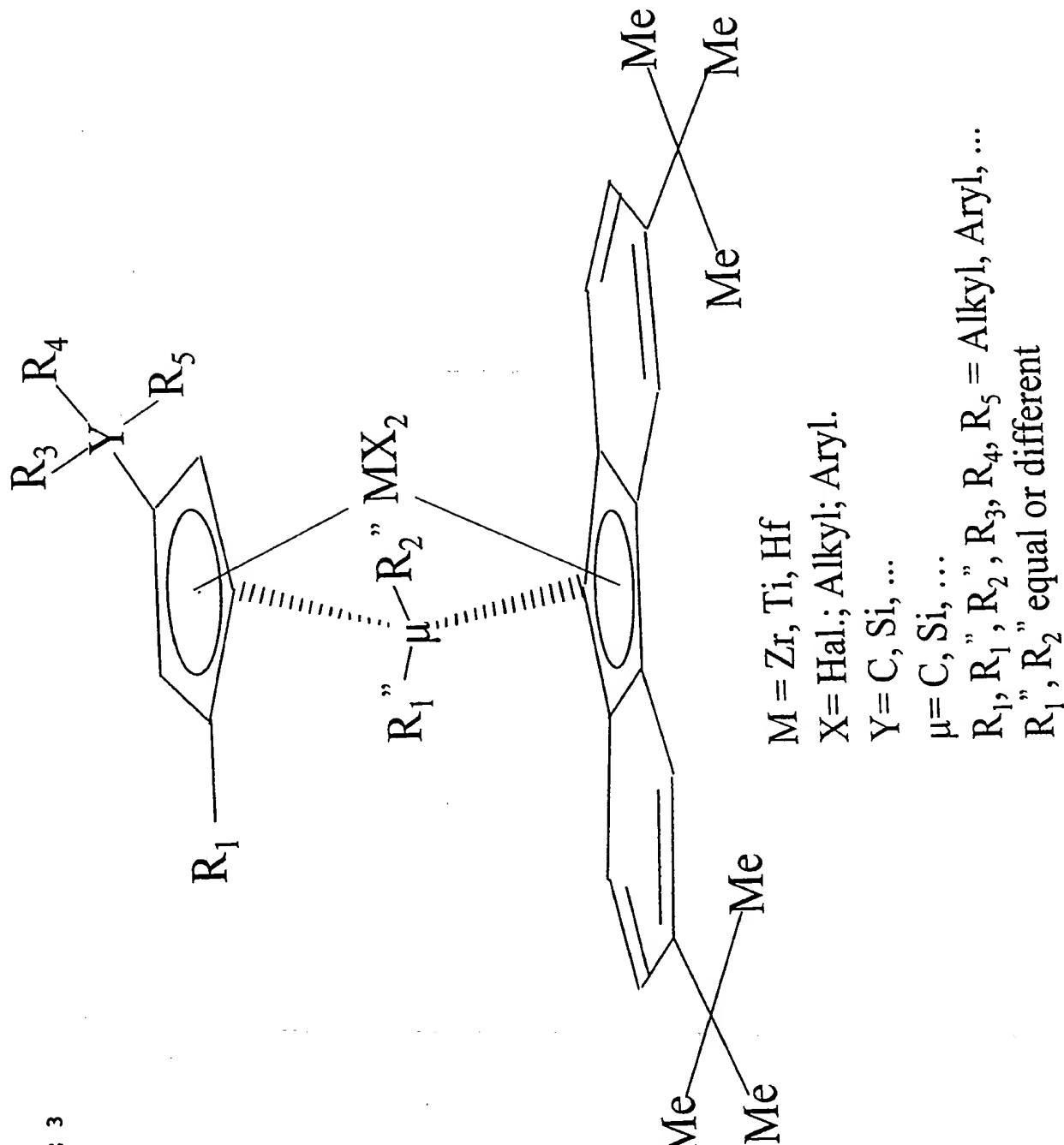


FIGURE 3

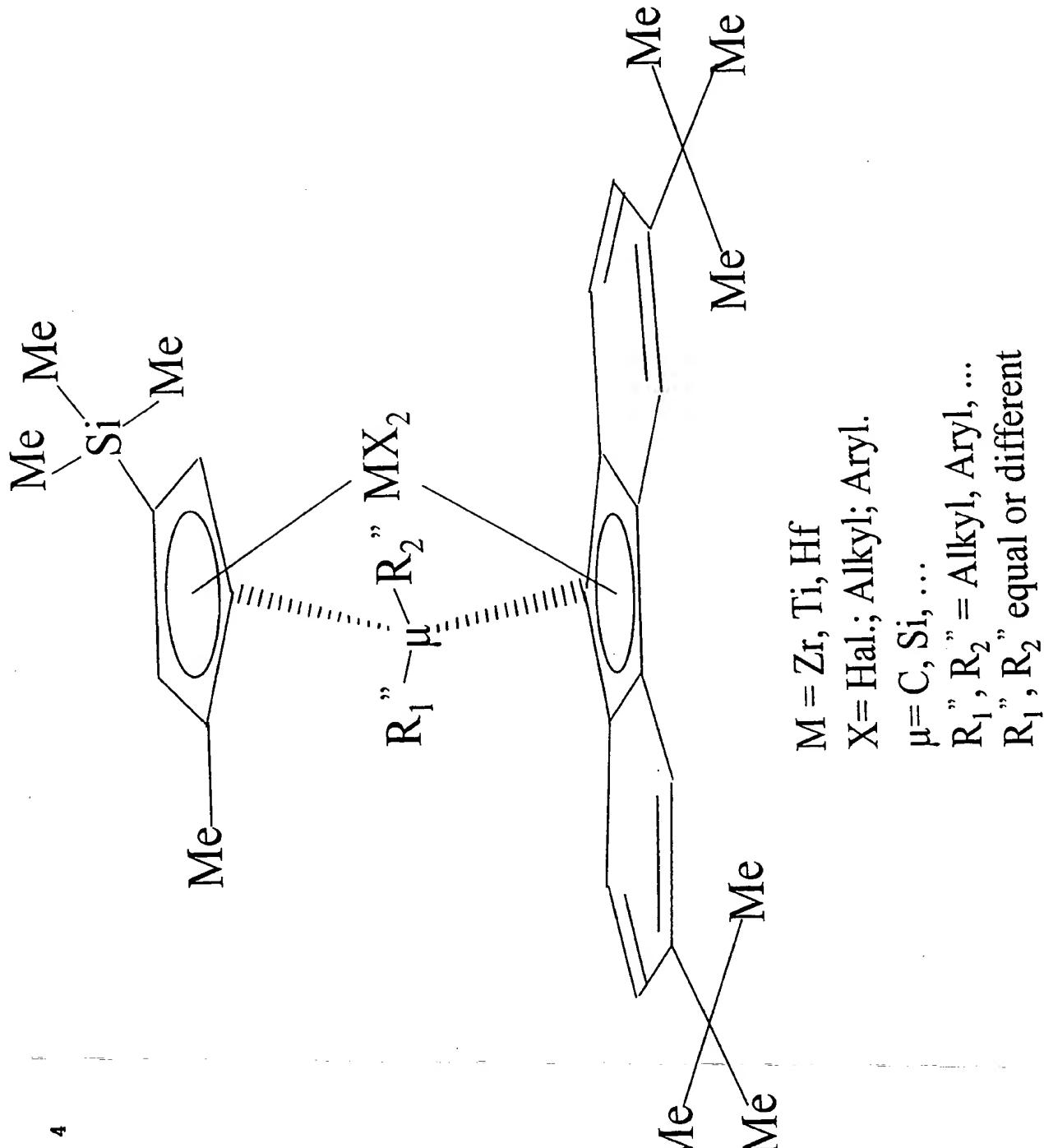


FIGURE 4

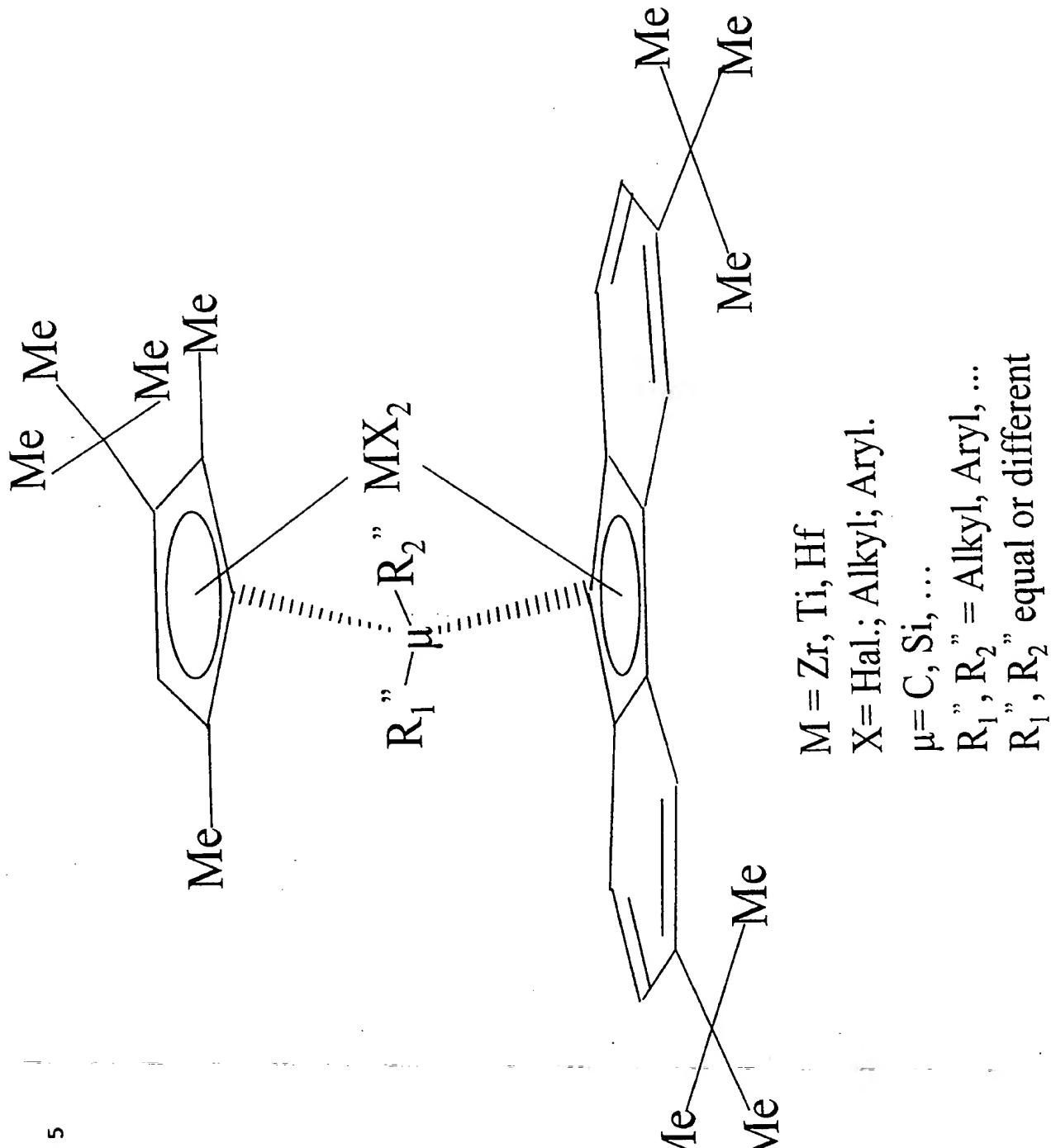


FIGURE 5

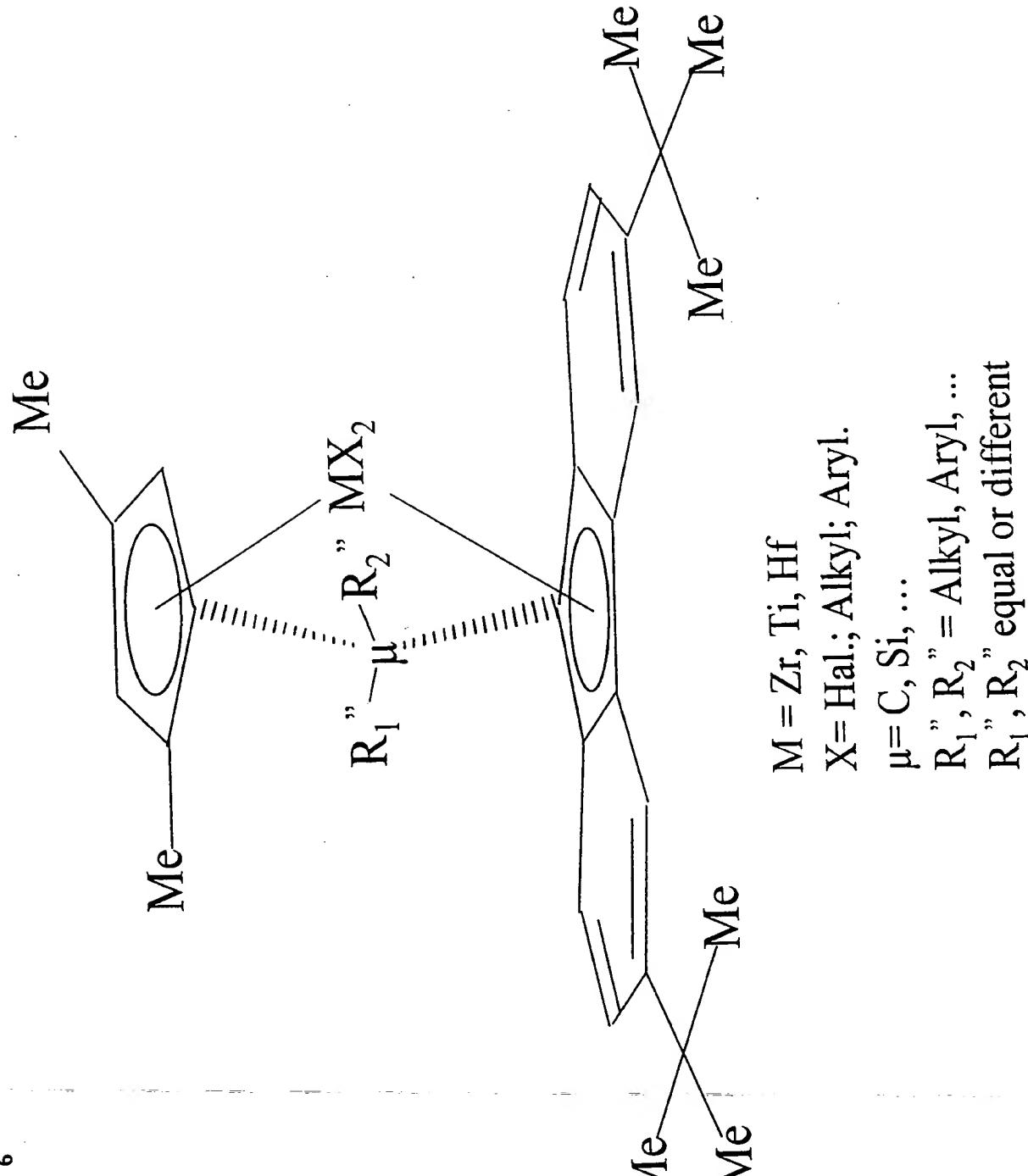
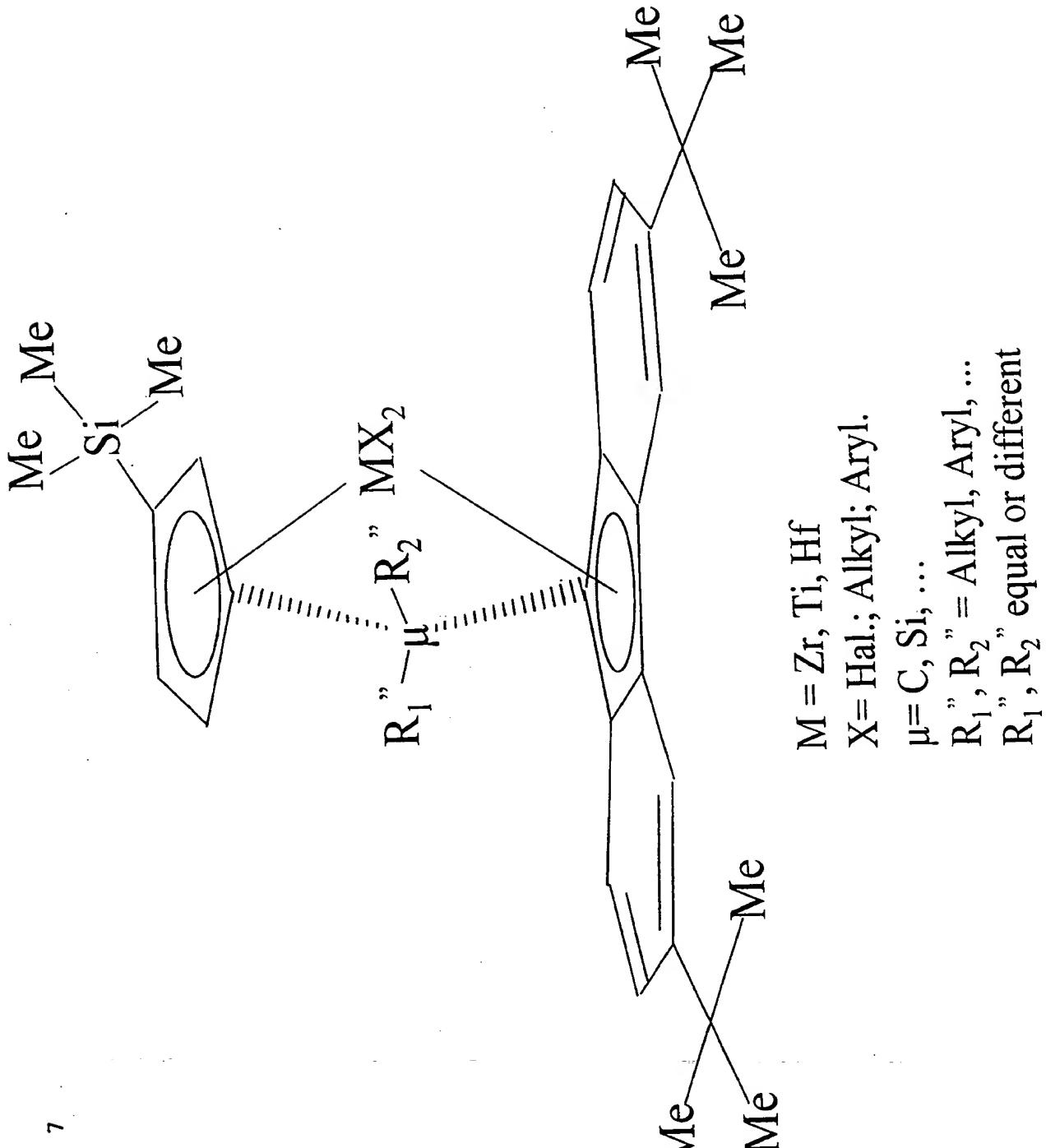


FIGURE 6



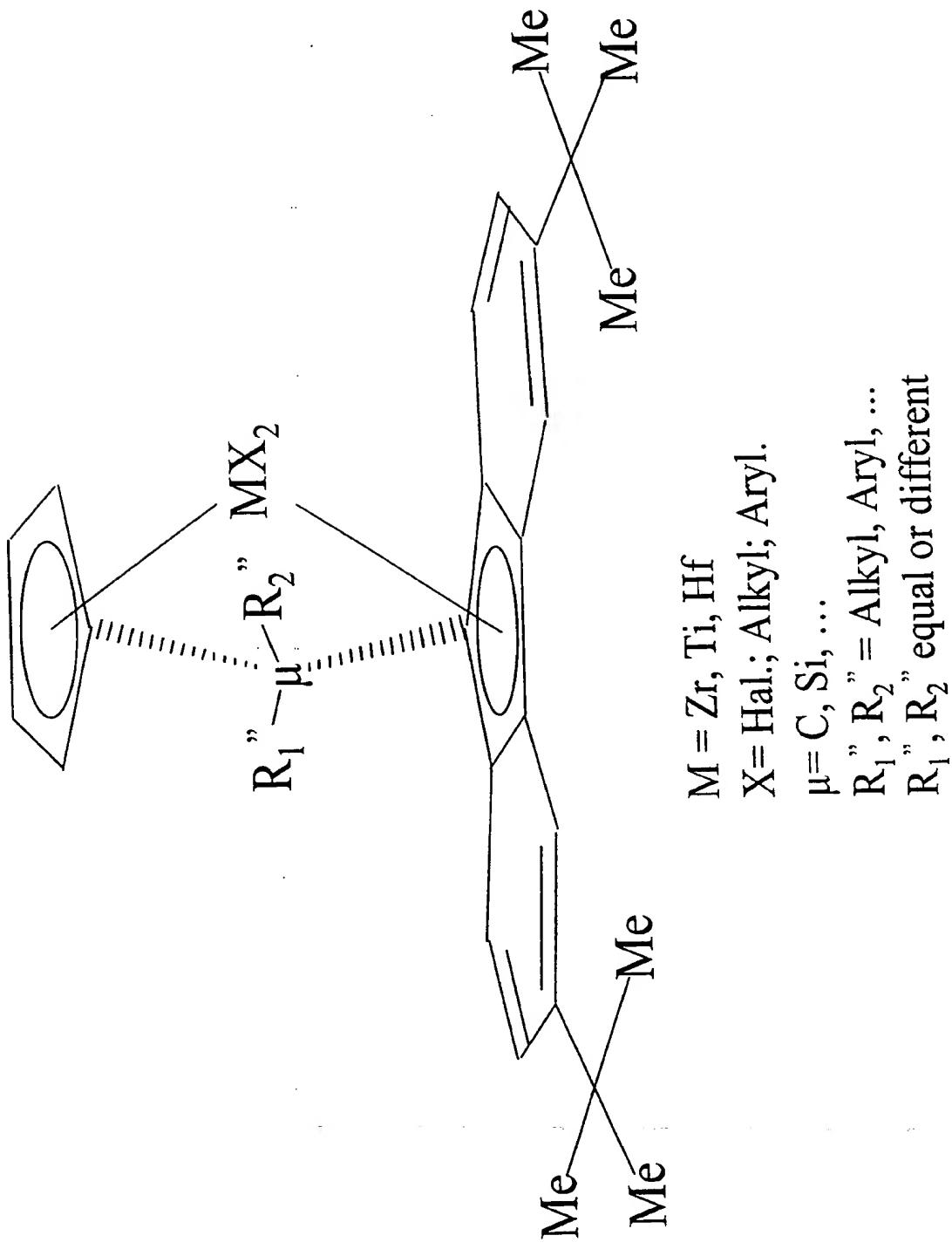


FIGURE 8

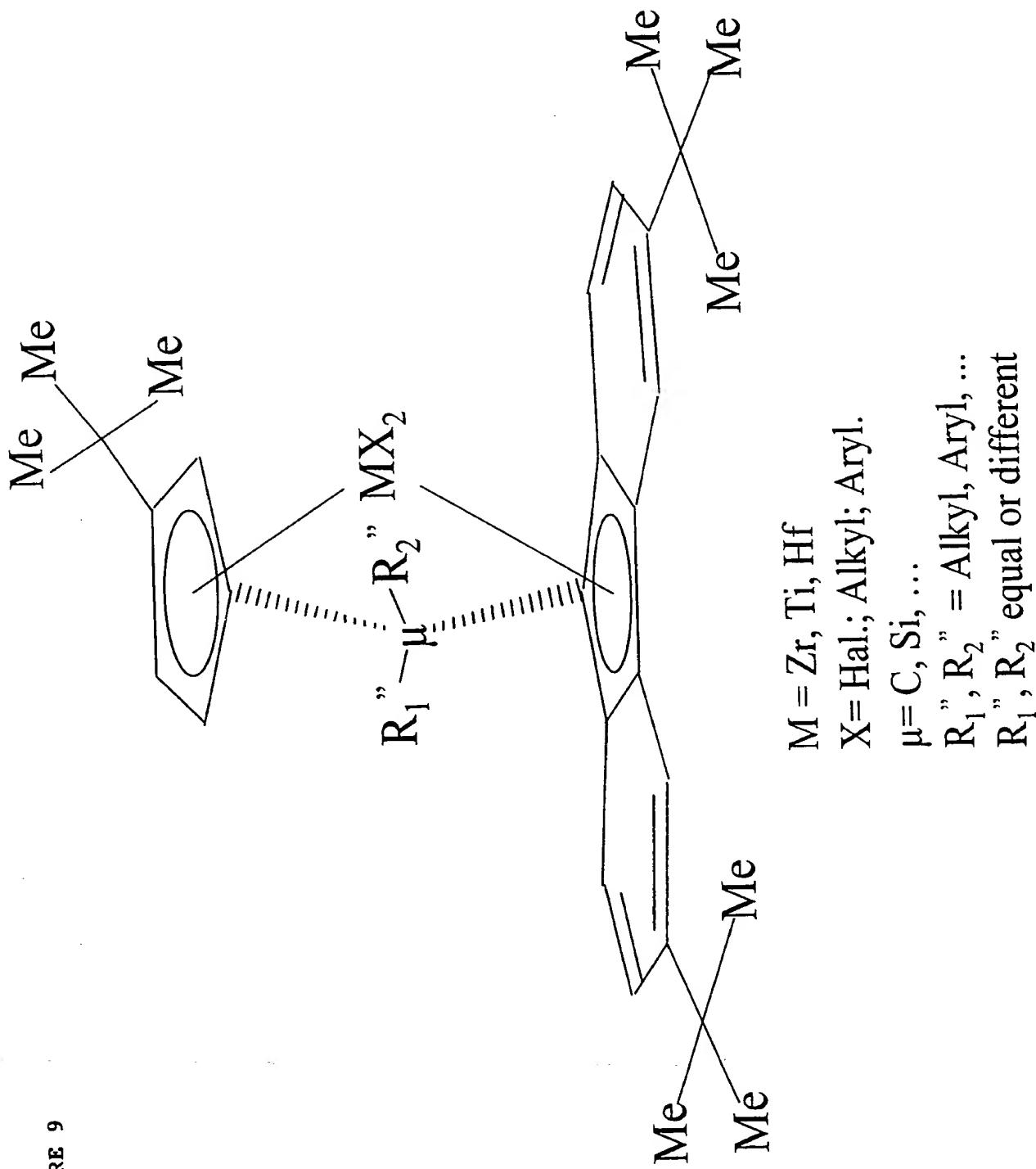


FIGURE 9

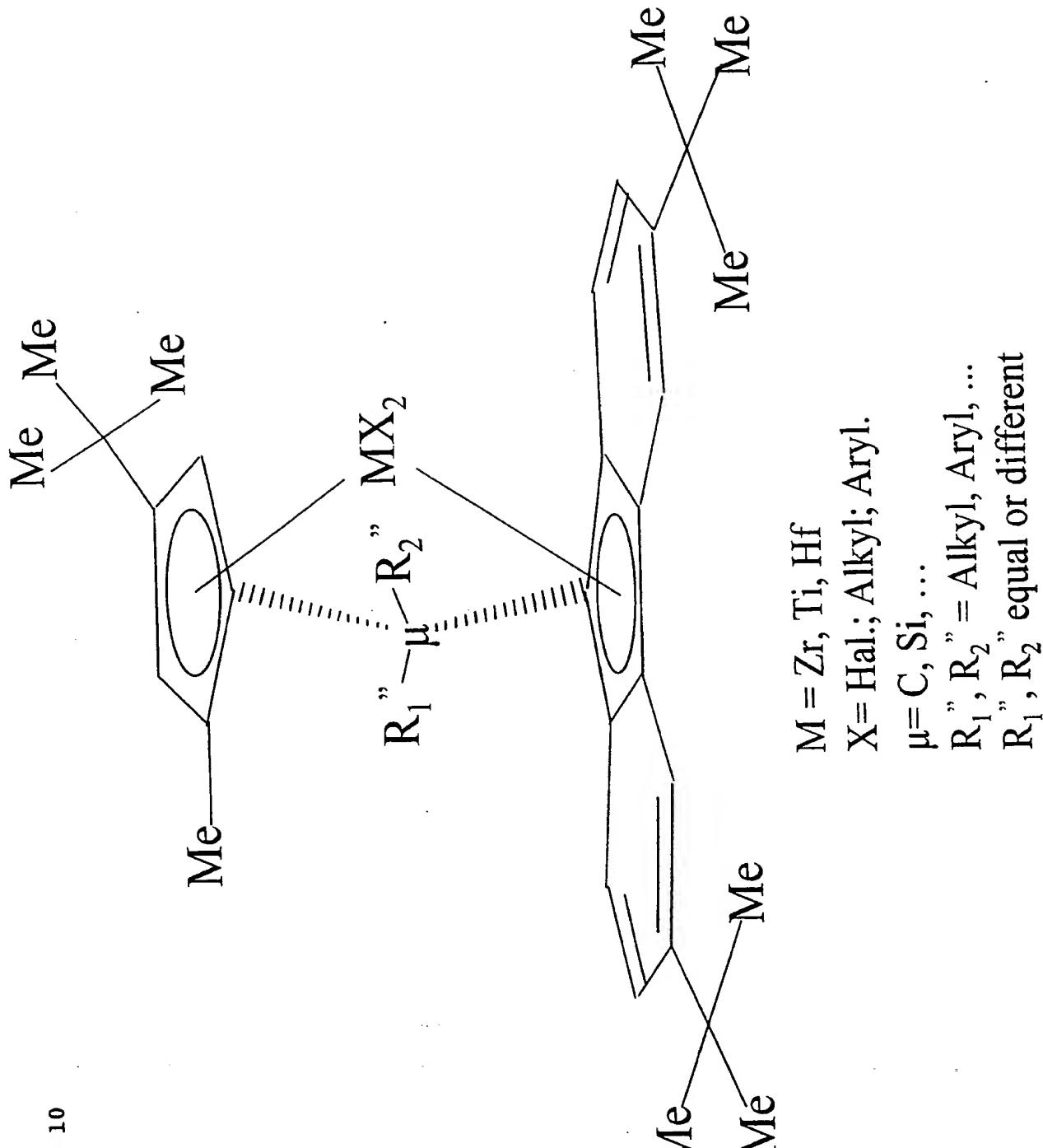


FIGURE 10

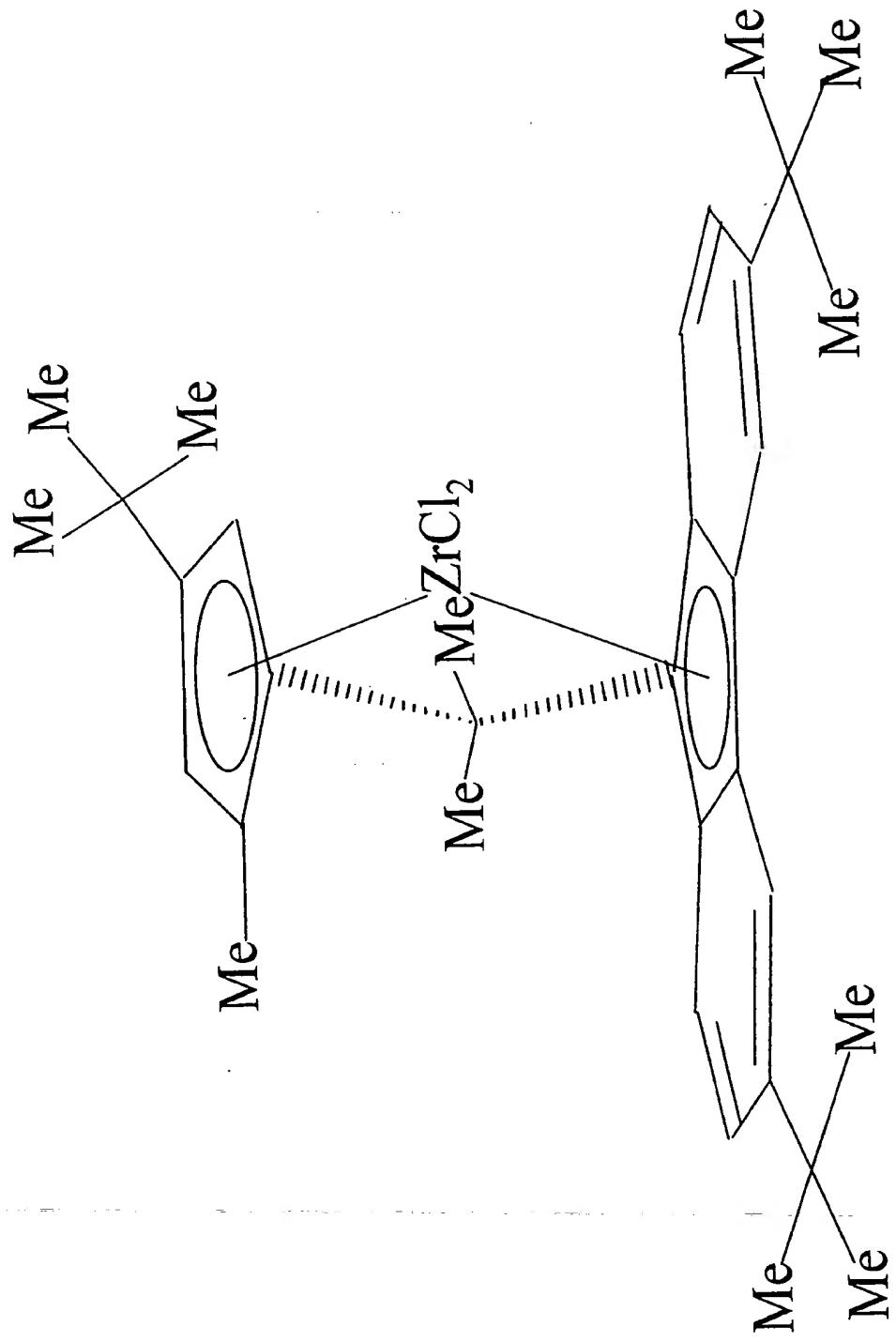


FIGURE 11

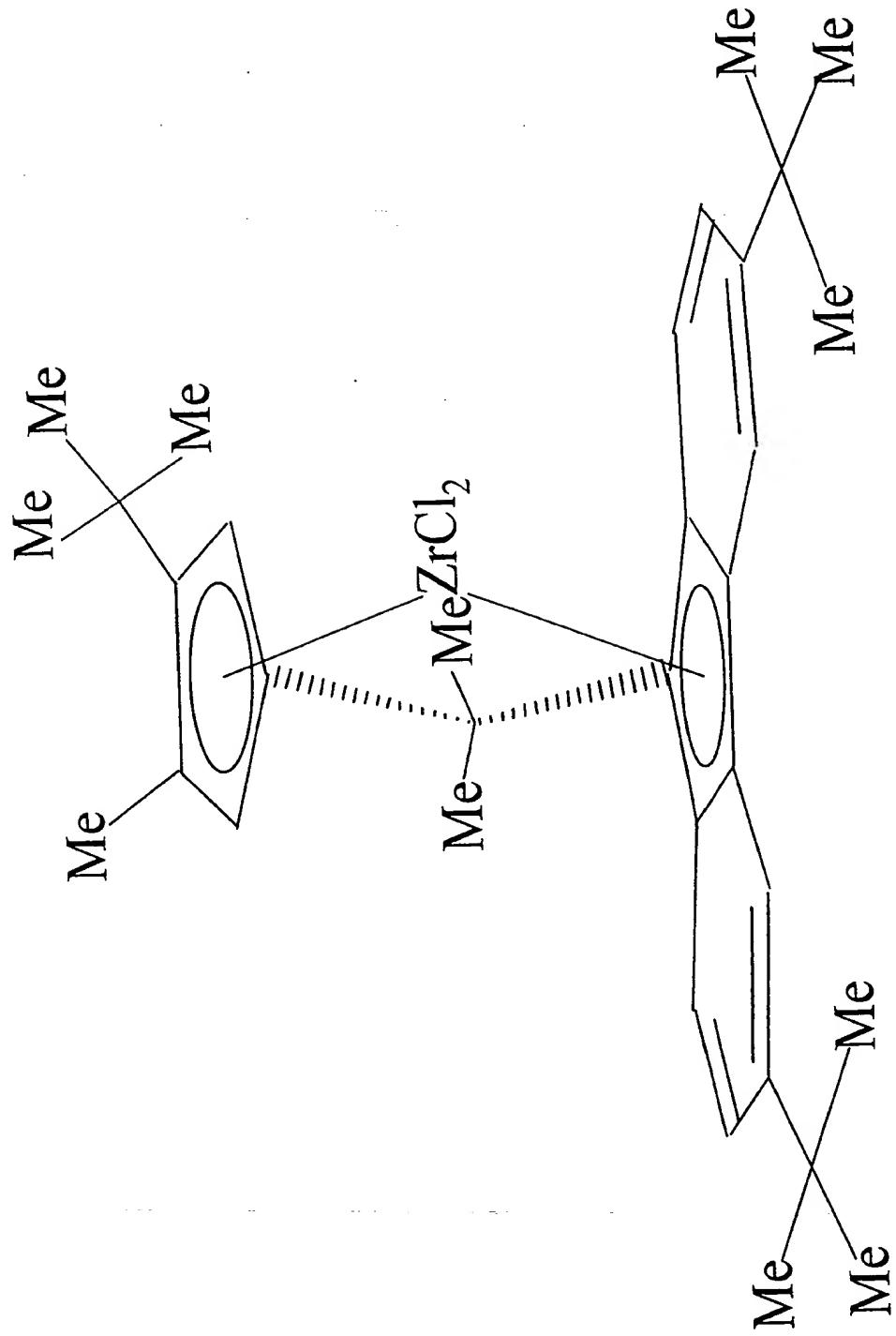
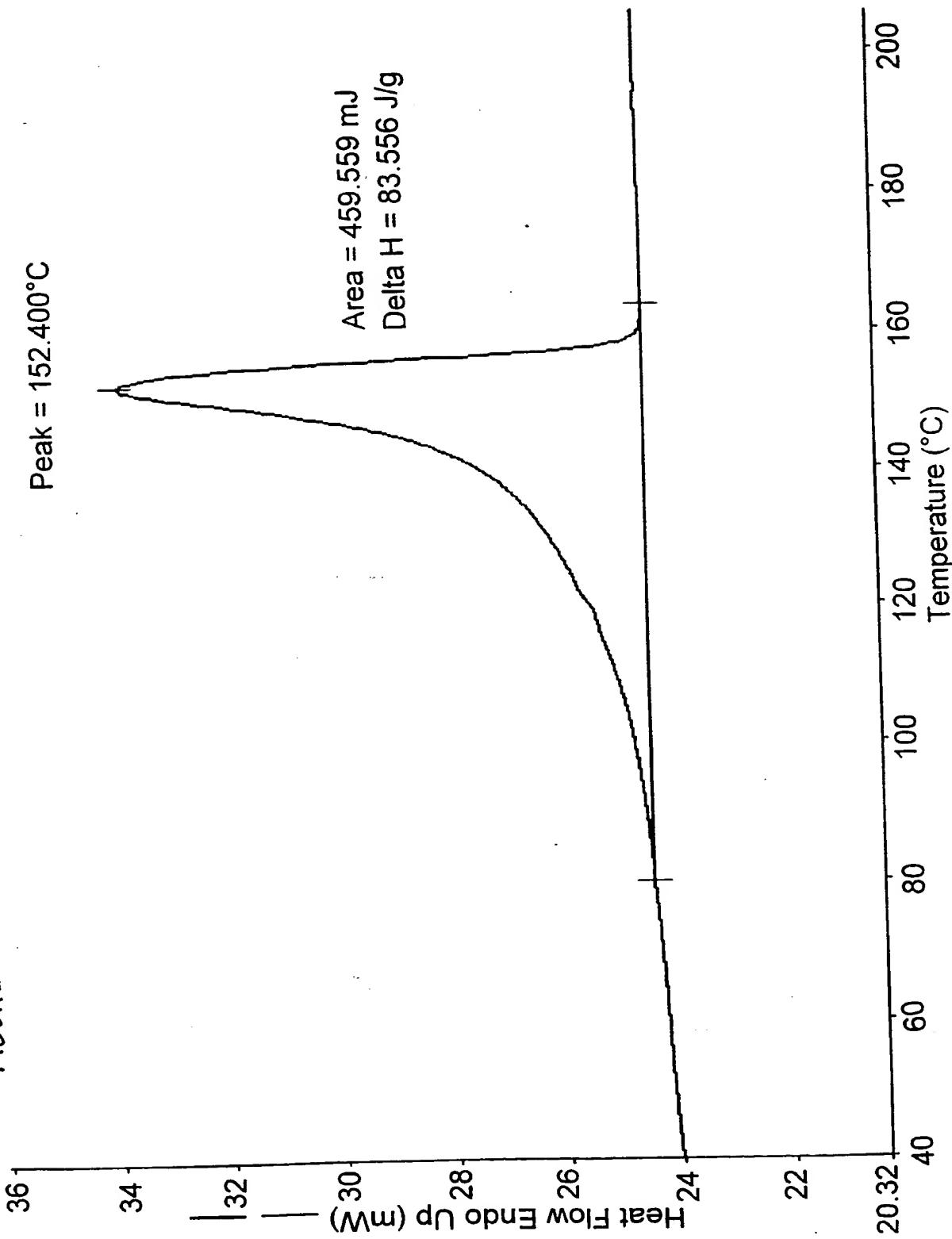


FIGURE 12

FIGURE 13



# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/EP 99/01094

**A. CLASSIFICATION OF SUBJECT MATTER**  
 IPC 7 C07F17/00 C08F4/64 C08F10/00

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
 IPC 7 C07F C08F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 780 396 A (HOECHST AG) 25 June 1997 (1997-06-25) column 9, line 58 - line 59 column 1, line 10 - line 18 ---	1-5, 7, 10-12, 21
X	EP 0 824 112 A (HOECHST AG) 18 February 1998 (1998-02-18)	1-5, 7, 10, 12, 21, 22, 28-30
Y	page 13, line 32, 34 page 19, line 12 - line 27 ---	13, 18-20, 25-27
		-/-

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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Date of the actual completion of the international search

25 October 1999

Date of mailing of the international search report

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## INTERNATIONAL SEARCH REPORT

International Application No  
PCT/EP 99/01094

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
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